

BELLCOMM, INC.

1100 Seventeenth Street, N.W. Washington, D. C. 20036

SUBJECT: Correlation of Predicted, Ground
Test, and Flight Thermal Behavior
in Gemini - Case 620

DATE: May 7, 1968

FROM: J. Gillespie

ABSTRACT

Reports were obtained from the Gemini Archives that presented the results of thermal qualification tests on the Gemini spacecraft and Gemini radiator tests conducted by McDonnell Aircraft Corporation. Little correlation was made in the thermal qualification tests between test results and theory other than that component temperatures remained within acceptable limits. Correlation between test results and theory in the radiator tests was poor. Reasons for the poor correlation are heat leaks, inability to duplicate exactly the solar and space environment, and unaccounted-for heat storage.

(NASA-CR-95416) CORRELATION OF PREDICTED,
GROUND TEST, AND FLIGHT THERMAL BEHAVIOR IN
GEMINI (Bellcomm, Inc.) 14 p

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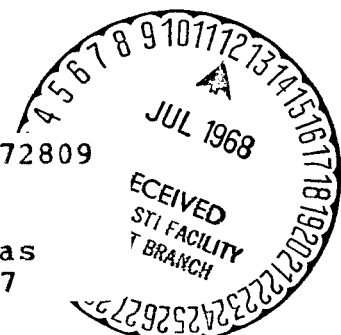
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MEMORANDUM FOR FILE

INTRODUCTION

A literature search of the Gemini Archives was conducted in order to correlate thermal flight test data and thermal vacuum test data with predicted results. Unfortunately, no thermal flight test data could be found in the Gemini Archives. The sequence and method of thermal qualification tests conducted by McDonnell are shown in Figure 1. Since the computer predictions were used to determine the external heat flux to be used in the thermal qualification testing, it is difficult to compare theoretical and test results. The thermal qualification tests are discussed in the following paragraphs. In addition, both theoretical and test results on the Gemini radiator are presented.

THERMAL QUALIFICATION TESTS

Three thermal qualification tests¹⁻³ were conducted with a production Gemini spacecraft in a high-vacuum chamber with a means of simulated solar heating effects and the heat sink characteristics of outer space during the period December 1964 to February 1965. The tests determined the thermal equilibrium characteristics of the Gemini spacecraft while operated in a simulated space environment and undergoing minimum and maximum combinations of internal and external heating effects. A schematic of the temperature control system is shown in Figure 2.

All tests were performed at a pressure less than 1×10^{-4} torr. Radiation from the spacecraft was absorbed by a liquid nitrogen shroud at a maximum temperature of -280°F and having a total emissivity greater than .9. Solar simulation was provided corresponding to three orbital flight paths: $\text{Beta} = 0^{\circ}, \pm 60^{\circ}$. Beta is defined as the geocentric angle between the sun and vehicle at noon orbital position. Equipment was operated on predetermined duty cycles corresponding to maximum and minimum anticipated system activity. The spacecraft was stationary during all tests. Thermal input of the crew was simulated to correspond to minimum and maximum activity levels. Test conditions are tabulated below:

Test	Condition	Equipment Heating	Crew Activity Level	Orbit	Coolant System
I	A	Minimum	1 resting/ 1 sleeping	$B = 0^{\circ}$	1 pump in 1 loop
	B	Minimum	1 resting/ 1 sleeping	$B = 60^{\circ}$	1 pump in 1 loop
	C	Minimum	1 resting/ 1 sleeping	$B = -60^{\circ}$	1 pump in 1 loop
II	A	Maximum	2 working	$B = 0^{\circ}$	2 pumps in 1 loop
	B	Maximum	2 working	$B = 60^{\circ}$	2 pumps in 1 loop
	C	Maximum	2 working	$B = -60^{\circ}$	2 pumps in 1 loop
III	A	Maximum	2 working	$B = 0^{\circ}$	1 pump in each of 2 loops
	B	Maximum	2 working	$B = 60^{\circ}$	1 pump in each of 2 loops
	C	Maximum	2 working	$B = -60^{\circ}$	1 pump in each of 2 loops

The external heat flux from solar, earth albedo, and earth emitted radiation was calculated by means of a computer program described in reference 4. Heat flux sensors monitored the incoming heat flux at various locations along the spacecraft and the external flux was matched to that calculated by the computer program. Various internal heating conditions were then used during the test and temperatures were monitored in various systems to determine if they exceeded specified operating limits of component parts.

GEMINI RADIATOR TEST RESULTS

A preliminary summary of Gemini radiator test results is presented in reference 5. Radiator coolant inlet and outlet temperatures for two different orbit conditions are shown in Figures 3 - 5. A comparison between test results and theoretically predicted results are shown. In general, agreement between test results and theory is poor. The adapter section containing the radiator is shown in Figure 7.

The factors according to McDonnell, that may cause the discrepancies in the results include the following:

1. The external heat inputs from the sun and earth simulation may be too high because of the inability of the test chamber to actually simulate the absolute zero sink temperature conditions of outer space. This can cause higher than predicted temperatures during low load operation.
2. The aft cover heat input was disregarded in the computer analysis. The aft cover can serve to improve radiator performance at both ends of the spacecraft electrical load range. It will tend to add heat during low load operation to raise the radiator temperature and improve equipment passive temperature control. During high load operation, the aft cover may even help increase the load carrying capability of the radiator because heat actually flows out through it.
3. There may be unaccounted for heat storage in the items which were assumed to be isolated from the radiator. These items include the adapter rings, the heat shield, retro-rockets, blast shield, and coldplate mounted adapter equipment. Extra heat storage capacity would tend to stabilize the temperature and even out the peaks and valleys of the temperature histories.
4. Heat leaks may be present with which the adapter oxidizer lines and coldplate mounted equipment lose heat through stray conduction and direct thermal radiation to the adapter walls.

The problem of heat leaks was studied. A heat leak could occur through any of the following paths:

1. Conduction through the module mounts.
2. Radiation to the plumbing and wiring and subsequent conduction through mount.
3. Conduction radially through the heat shield to the edge ring and axially across the heat shield to the cold chamber.
4. Radiation back to the aft cover internal surface and then to the chamber cold wall from the aft cover external surface.

Evaluation of the various possible heat leaks brought out the following results:

1. While conduction through the module mounts definitely contributed to the problem, the magnitude of this heat loss is not sufficient to account for the total heat leak.
2. Radiation to the plumbing and wiring and subsequent conduction to the cold wall could not be the major loss. Otherwise a significant increase in bulk equipment temperature would have occurred by the addition of the radiation shield over more than 50% of these areas.
3. Conduction losses from the heat shield must be one of the major leaks because the heat shield is one of the colder pieces of equipment in the retro section.
4. Radiant losses back through the aft cover were definitely one of the major losses since it was determined that the external emissivity of the simulated aft cover was of the order of .21 to .25 instead of below .1 as initially estimated.

Based on qualitative analysis of the radiator test results, the following conclusions were made:

1. The radiator performance was slightly better than expected.
2. The temperature control system was inadequate for long missions at low electrical loads.

The potential freezing problem areas were:

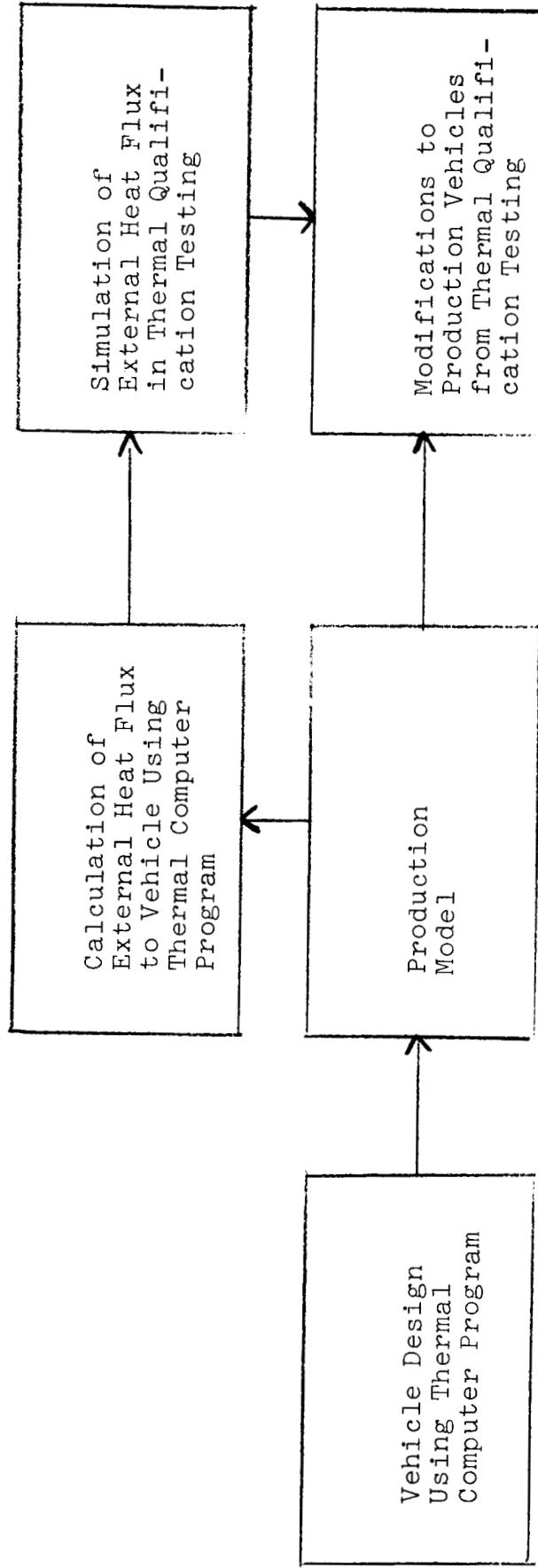
1. Water lines.
2. Oxidizer lines and valves.
3. Water tanks.
4. Oxidizer tanks.

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J. Gillespie

FIGURE 1

SEQUENCE OF GEMINI VEHICLE
THERMAL DESIGN



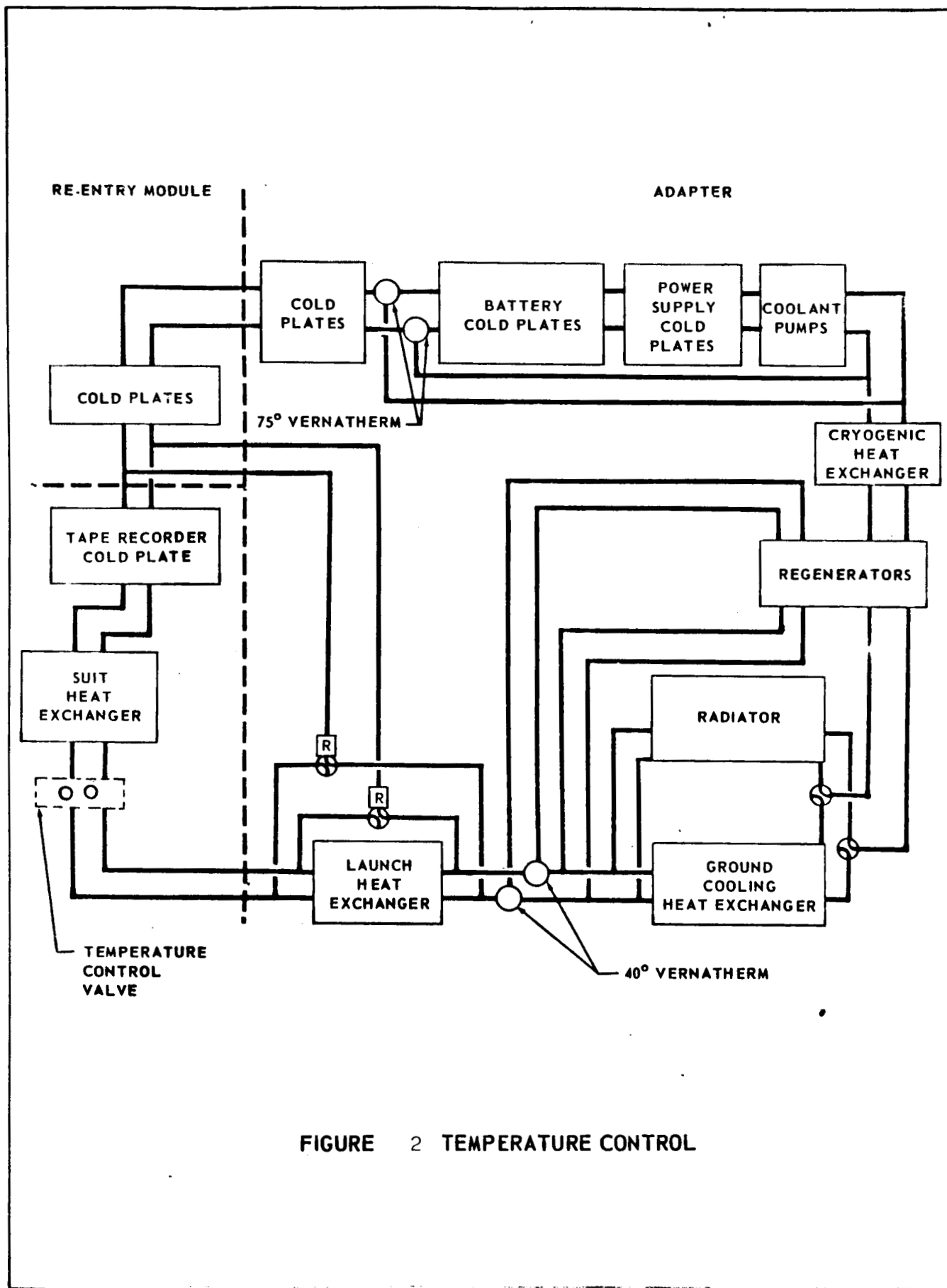


FIGURE 2 TEMPERATURE CONTROL

FIGURE 3

RADIATOR COOLANT INLET TEMPERATURE
464 WATTS ELECTRICAL LOAD FUEL CELLS
PRIMARY LOOP ONLY 75°F CONTROL VALVE $\beta = 0^\circ$

--- CALCULATED ORBIT TEMPERATURES IBM CASE T128-3-322
O.O.O. TEST DATA TR 052-068.06 RUN # 1 (REPEAT) 3-26-64

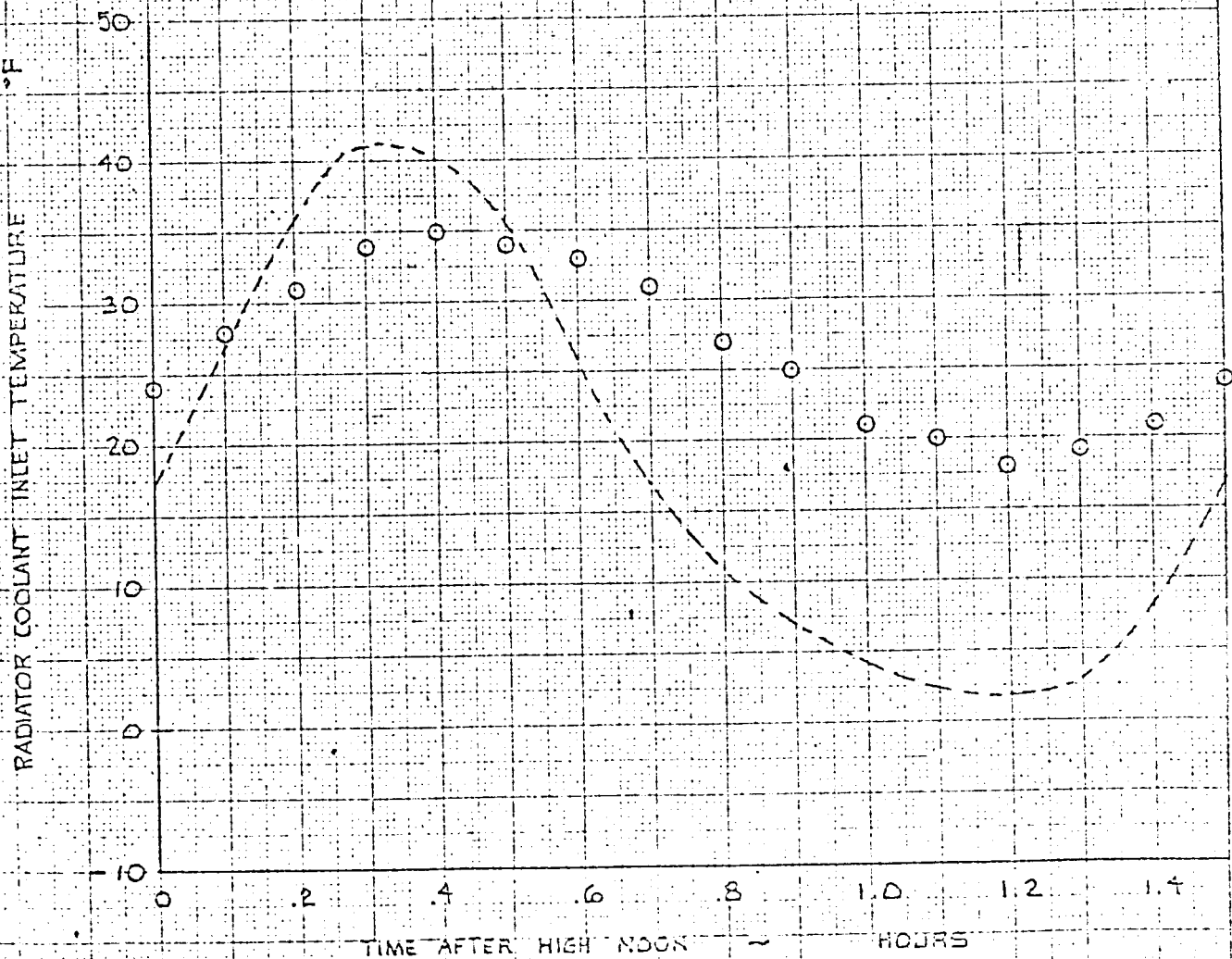


FIGURE 5

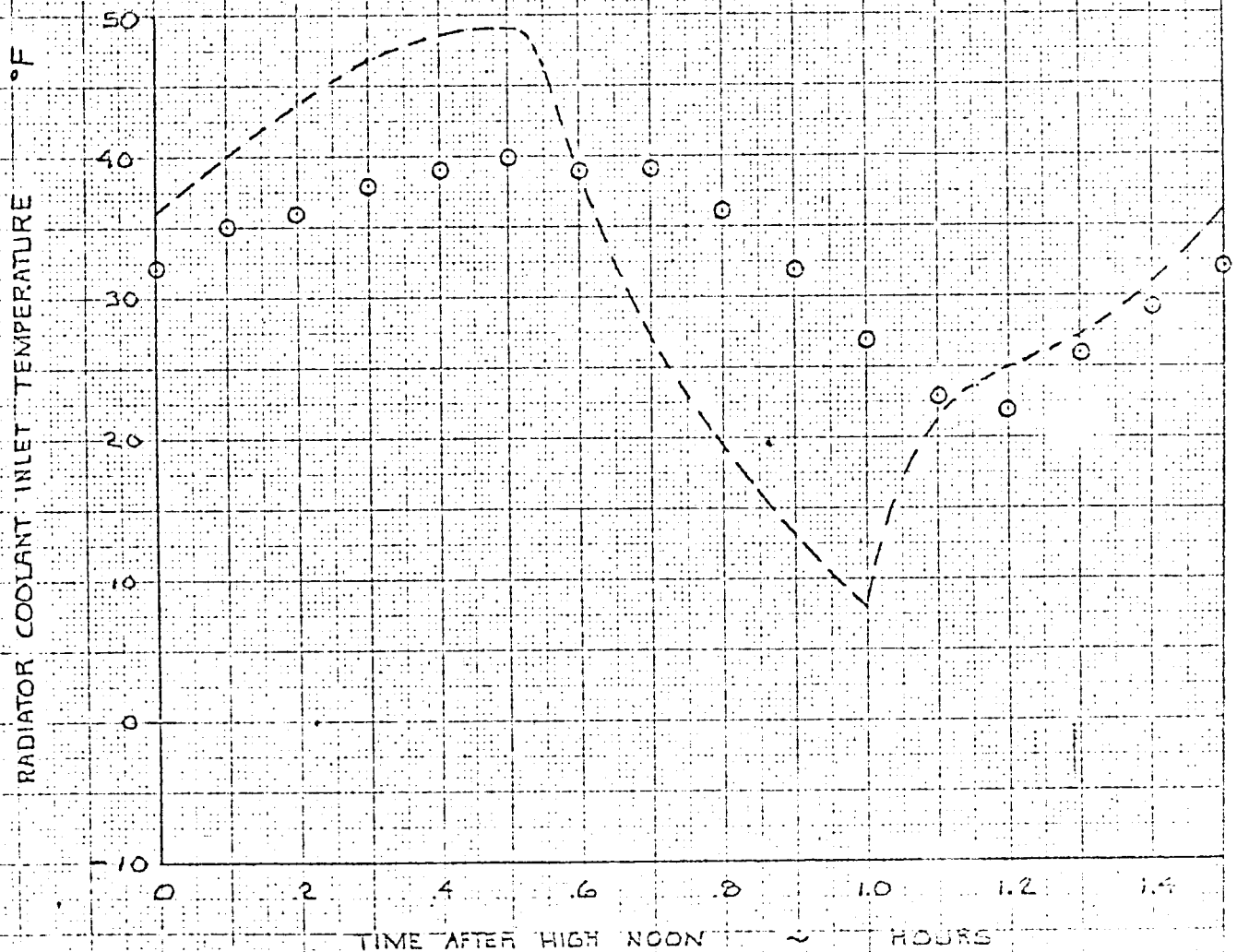
RADIATOR COOLANT INLET TEMPERATURE

464 WATTS ELECTRICAL LOAD FUEL CELLS

PRIMARY LOOP ONLY 75°F CONTROL VALVE $R = +60^\circ$

--- CALCULATED ORBIT TEMPERATURES. IBM CASE T128-3-328

O O O TEST DATA TR 082-068.06 RUN # 5 3-27-64.



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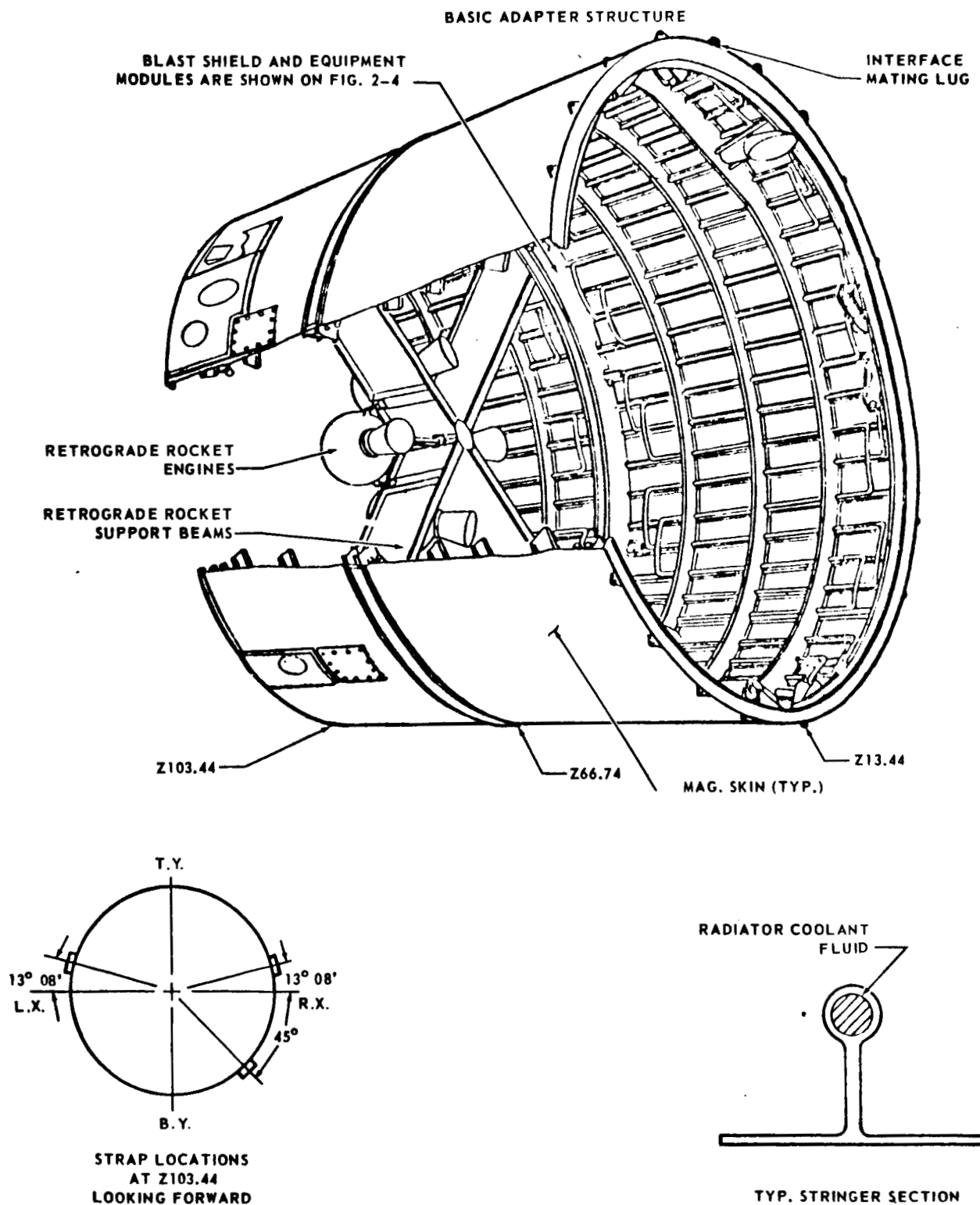


FIGURE 7 ADAPTER STRUCTURE

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REFERENCES

1. "Gemini Spacecraft 3A, Thermal Test #1, Test Results Report," Report No. B427, January 12, 1965, McDonnell Aircraft Corporation.
2. "Gemini Spacecraft 3A, Thermal Test #2, Test Results Report," Report No. B427-1, February 15, 1965, McDonnell Aircraft Corporation.
3. "Gemini Spacecraft 3A, Thermal Test #3, Test Results Report," Report No. B427-2, March 23, 1965, McDonnell Aircraft Corporation.
4. "Program for Determining the Thermal Environment and Temperature History of Orbiting Space Vehicles," Thermodynamics Technical Note #16, McDonnell Aircraft Corporation.
5. "Preliminary Analysis of Gemini Radiator Test Data," Thermodynamics Technical Note #104, May 15, 1964, McDonnell Aircraft Corporation.

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